

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

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SEMICONDUCTOR DEVICE HAVING A BALL GRID  
ARRAY AND A FABRICATION PROCESS THEREOF

of which the following is a specification : -

1     TITLE OF THE INVENTION

          SEMICONDUCTOR DEVICE HAVING A BALL GRID  
ARRAY AND A FABRICATION PROCESS THEREOF

5     BACKGROUND OF THE INVENTION

          The present invention generally relates to  
semiconductor devices having a ball grid array (BGA)  
contact structure and more particularly to a so-called  
micro-BGA device in which a circuit substrate is  
10    provided on a semiconductor chip with a size smaller  
than an outer dimension of the semiconductor chip.

          FIG.1 shows a conventional semiconductor  
device having a BGA contact structure.

          Referring to FIG.1, the semiconductor device  
15    includes a circuit substrate 36 and a semiconductor  
chip 32 provided on a top surface of the circuit  
substrate 36. Further, electrodes on the  
semiconductor chip 32 are electrically interconnected  
to corresponding electrodes formed on the top surface  
20    of the circuit substrate 36 by way of a bonding wire  
34. The electrodes on the top surface of the circuit  
substrate 36 are in turn interconnected to respective  
corresponding electrodes on a bottom surface of the  
circuit substrate 36 via through-holes (not shown)  
25    provided in the circuit substrate 36. The circuit  
substrate 36 further carries solder bumps 37 on the  
bottom surface in correspondence to the electrodes  
provided thereon. The semiconductor chip 32 on the  
top surface of the circuit substrate 36 is  
30    encapsulated by a resin package body 31 together with  
the bonding wire 34.

          FIG.2 shows another conventional BGA  
semiconductor device disclosed in the United States  
Patent 5,148,265.

35       Referring to FIG.2, the BGA semiconductor  
device is distinct over the semiconductor device of  
FIG.1 in that a circuit substrate 46 corresponding to

1 the circuit substrate 36 of FIG.1 is now provided on a  
top surface of a semiconductor chip 42 corresponding  
to the semiconductor chip 32, with a size smaller than  
an outer size of the semiconductor chip 42. Such a  
5 BGA device that uses a circuit substrate having an  
outer size smaller than the outer size of a  
semiconductor chip is called a micro-BGA device. In  
the micro-BGA device of FIG.2, it should be noted that  
the solder bumps (not shown) are provided on  
10 electrodes 43 formed on the circuit substrate 46.

In the foregoing conventional BGA device of  
FIG.1, there arises a problem in that, because of the  
lateral size of the circuit substrate exceeding the  
size of the semiconductor chip, the overall size of  
15 the semiconductor device tends to become excessively  
large and a high-density mounting of the device on an  
electronic apparatus is difficult.

In the foregoing micro-BGA device of FIG.2,  
on the other hand, it is necessary to bond the circuit  
20 substrate, of which size is smaller than a size of the  
semiconductor chip, on the semiconductor chip, while  
handling or alignment of such a small semiconductor  
chip or small circuit substrate is difficult and  
increases the number of fabrication steps as well as  
25 the cost of the semiconductor device.

#### SUMMARY OF THE INVENTION

Accordingly, it is a general object of the  
present invention to provide a novel and useful  
30 semiconductor device and a fabrication process thereof  
wherein the foregoing problems are eliminated.

Another and more specific object of the  
present invention is to provide a semiconductor device  
including a semiconductor chip and a circuit  
35 substrate, wherein the semiconductor device has an  
outer size substantially identical with an outer size  
of the semiconductor chip, and wherein the circuit

1 substrate is attached to the semiconductor chip by a  
simple and easy process.

Another object of the present invention is  
to provide a method of fabricating a semiconductor  
5 device, comprising the steps of:

forming an electronic circuit on a wafer in  
a region defined by a scribe line, said wafer carrying  
a first electrode thereon;

attaching a circuit substrate carrying  
10 thereon a predetermined conductor pattern, on said  
wafer, said circuit substrate carrying a second  
electrode and a third electrode, said step of  
attaching said circuit substrate including a step of  
aligning said circuit substrate with respect to said  
15 electronic circuit in said wafer;

interconnecting said first electrode on said  
wafer and second electrode of said predetermined  
conductor pattern by a wire bonding process;

forming a spherical electrode on said third  
20 electrode; and

dicing said wafer along said scribe line.

Another object of the present invention is  
to provide a semiconductor device, comprising:

a semiconductor chip having a top surface,  
25 said semiconductor chip carrying a first electrode;  
a circuit substrate attached to a top  
surface of said semiconductor chip, said circuit  
substrate carrying thereon a predetermined conductor  
pattern including a second electrode and a third  
30 electrode;

a resin layer intervening between said top  
surface of said semiconductor chip and said circuit  
substrate;

a spherical electrode provided on said  
35 circuit substrate in correspondence to said third  
electrode;

a bonding wire electrically interconnecting

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1 said second electrode of said predetermined conductor  
pattern on said circuit substrate and said first  
electrode on said semiconductor chip; and

5 a resin potting encapsulating said bonding  
wire including said first and second electrodes,  
said chip and said resin potting being  
defined by a common edge surface substantially  
perpendicular to a principal surface of said  
substrate.

10 Another object of the present invention is  
to provide a semiconductor device, comprising:

a semiconductor chip having a top surface,  
said semiconductor chip carrying a first electrode;

15 a circuit substrate attached to a top  
surface of said semiconductor chip, said circuit  
substrate carrying thereon a predetermined conductor  
pattern including a second electrode and a third  
electrode;

20 a spherical electrode provided on said  
circuit substrate in correspondence to said third  
electrode;

25 a bonding wire electrically interconnecting  
said second electrode of said predetermined conductor  
pattern on said circuit substrate and said first  
electrode on said semiconductor chip;

a resin potting encapsulating said bonding  
wire including said first and second electrodes;

a resin side wall cover covering a side wall  
of said circuit substrate;

30 said chip having a side wall substantially  
flush to an outer surface of said resin side wall  
cover, said side wall of said chip being substantially  
perpendicular to a principal surface of said chip.

35 According to the present invention, the  
semiconductor wafer, in which a number of  
semiconductor chips are formed as an integral  
monolithic body, is diced after the circuit substrate

1 is attached thereto. Thereby, the adjustment for a  
proper positioning between the chip and the circuit  
substrate is achieved easily for each chip by merely  
conducting a positioning adjustment between the  
5 semiconductor wafer as a whole and a master circuit  
substrate that includes the circuit substrates with a  
large number in a mechanically interconnected state.

Other objects and further features of the  
present invention will become apparent from the  
10 following detailed description when read in  
conjunction with the attached drawings.

#### BRIEF DESCRIPTION OF THE INVENTION

FIG.1 is a diagram showing the construction  
15 of a conventional semiconductor device;

FIG.2 is a diagram showing the construction  
of another conventional semiconductor device;

FIG.3 is a diagram showing the construction  
of a semiconductor device according to a first  
20 embodiment of the present invention;

FIG.4 is a diagram showing the construction  
of the semiconductor of FIG.3 in an oblique view with  
a part thereof removed;

FIGS.5A - 5F are diagrams showing a  
25 fabrication process of the semiconductor device of the  
first embodiment;

FIGS.6A and 6B are diagrams showing a  
modified fabrication process of the semiconductor  
device of the first embodiment;

30 FIG.7 is a diagram showing a fabrication  
process of a semiconductor device according to a  
second embodiment of the present invention;

FIG.8 is a diagram showing the semiconductor  
device of the second embodiment in a cross-sectional  
35 view;

FIG.9 is a diagram showing the semiconductor  
of the second embodiment in an oblique view;

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1           FIG.10 is a diagram showing the construction  
of a semiconductor device according to a third  
embodiment of the present invention; and

          FIGS.11A - 11F are diagrams showing the  
5       fabrication process of the semiconductor device of the  
third embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[FIRST EMBODIMENT]

10           FIG.3 shows a semiconductor device 5  
according to a first embodiment of the present  
invention in a cross-sectional view, while FIG.4 shows  
the same semiconductor device 5 formed on a  
semiconductor wafer 2A such as a Si wafer in an  
15       oblique view for a state before the semiconductor  
wafer 2A is diced into individual semiconductor chips  
2 along a scribe line 2B.

          Referring to FIG.3, the semiconductor device  
5 is constructed on the semiconductor chip 2 and  
20       includes a circuit substrate 6 that is provided on the  
semiconductor chip 2, with an intervening adhesive  
layer 3a that causes the circuit substrate 6 to adhere  
to the semiconductor chip 2 firmly. The chip 2  
carries thereon an electrode pad 8a that is connected  
25       electrically to a corresponding electrode pad 8b on  
the circuit substrate 6 by way of a bonding wire 4.  
Further, the bonding wire 4 is embedded in a resin  
potting 1.

          In the construction of the semiconductor  
30       device 5 of the present embodiment, the electrical  
signal appearing on the electrode pad 8a of the chip 2  
is forwarded to the electrode pad 8b on the circuit  
substrate 6 by way of a bonding wire 4 and further to  
an electrode pad 8c on the circuit substrate 6 by way  
35       of a conductor pattern 9 provided on the circuit  
substrate 6. The electrode pad 8c carries thereon a  
spherical or semi-spherical solder bump 7 or a

1 suitable spherical electrode. It should be noted that  
the conductor pattern 9 on the circuit substrate 6 is  
covered by a solder resist layer 3b, and the solder  
bump 7 projects outwardly from the solder resist layer  
5 3b that covers the surface of the circuit substrate 6.  
It should be noted that the layer 3b is not  
illustrated in FIG.3.

It should be noted that the semiconductor  
chip 2 is fabricated according to a standard  
10 fabrication process of an integrated circuit and  
supplies the output electrical signal to the electrode  
pad 8a provided thereon.

On the other hand, the adhesive layer 3a is  
formed of an adhesive material constituted by a  
15 principal resin component and a solvent that dissolves  
a flexibilizer. For example, a reactive thermoplastic  
resin that contains a carboxyl group or a denatured  
maleic acid anhydride may be used for the principal  
resin, while a reactive silicone such as a silicone  
20 having an epoxy group may be used for the  
flexibilizer.

More specifically, a bisphenol A-type epoxy  
resin may be used for a binder resin of the adhesive  
layer 3a in combination with a suitable amount of  
25 phenol novolak resin, which is used as a curing agent.  
The binder and the curing agent are then diluted by  
butylcellosolve acetate and mixed by a rolling  
process. Further, sieved Al particles having an  
average diameter in the range of 3 - 30  $\mu\text{m}$  are added  
30 further to the mixture thus obtained, with a  
proportion such that the adhesive layer contains, in a  
completely cured state thereof, the Al particles with  
a proportion of about 30 vol%. The target adhesive is  
then obtained by adding triphenylphosphine further to  
35 the mixture as a cure accelerator, shortly before the  
end of the roll mixing process, with a proportion of  
about 2 wt% with respect to the 100 wt% of the epoxy



1 resin.

The bonding wire 4, on the other hand, may be formed of a wire of gold or aluminum having a diameter of 25 - 30  $\mu\text{m}$  and is bonded to the electrode 8a or 8b by using an ordinary wire bonding apparatus. In the present invention, a first bonding process is conducted to the electrode 8a on the chip, followed by a second bonding process that is conducted to the electrode 8b, for reducing the overall height of the semiconductor device 5.

The circuit substrate 6 is formed of a glass epoxy or polyimide and is bonded to the semiconductor chip 2 by way of the adhesive layer 3a as indicated in FIG.3. It should be noted that the circuit substrate 6 carries thereon the conductor pattern 9, such that the conductor pattern 9, which may be formed of Cu, extends from the electrode 8b to the electrode 8c on which the solder bump 7 is formed. The conductor pattern 9 can be formed in any desired shape by conducting an etching process.

The solder bump 7 is typically formed of an alloy containing 60 wt% of Sn and 40 wt% of Pb, wherein the composition of the solder bump 7 may be adjusted appropriately depending upon the necessary or desired characteristics of the solder bump. Thus, the solder bump 7 may contain other elements than Sn or Pb. Further, the solder bump 7 may be formed by plating a solder alloy around a spherical or semi-spherical core of Cu or a resin.

FIGS.5A - 5F show the fabrication process of the BGA device 5 of FIG.3.

Referring to FIG.5A, the adhesive layer 3a is provided on a top surface of a semiconductor wafer 10, wherein the semiconductor wafer 10 includes a number of electronic devices in respective regions each defined by a scribe line 51 and corresponding to a chip, as a monolithic integral body. The adhesive

1 layer 3a is formed by a suitable process such as a  
screen printing process that uses a metal mask or a  
screen mask. Alternatively, the adhesive layer 3a may  
be formed by a potting process.

5 Next, in the step of FIG.5B, a master  
circuit substrate 6A is mounted on the adhesive layer  
3a, wherein the master circuit substrate 6A includes a  
number of the circuit substrates 6 in a mechanically  
interconnected state by a bridging part 6B. The  
10 master circuit substrate 6A is thereby adjusted with  
respect to the electronic devices formed on the wafer  
10 such that each of the circuit substrates 6 included  
in the master circuit substrate 6A achieves a proper  
alignment to the corresponding electronic device on  
15 the wafer 10. Thereafter, the adhesive layer 3a is  
cured and the master circuit substrate 6A is firmly  
attached to the wafer 10 via the adhesive layer 3a.  
In the construction of FIG.5B, it should be noted that  
there is formed a groove in correspondence to the  
20 scribe line 51 such that the top surface of the wafer  
10 is exposed at the groove 51.

Of course, it is possible to form the master  
circuit substrate 6A first and attach the  
semiconductor wafer 10 to the circuit substrate 6A by  
25 interposing the adhesive layer 3a therebetween.

Next, in the step of FIG.5C, the electrode  
pads (not shown) on the wafer 10 exposed by the groove  
51 are interconnected to corresponding electrode pads  
on the master circuit substrate 6A by respective  
30 bonding wires 4, by conducting a wire bonding process  
in each of the regions of the wafer 10 and in each of  
the circuit substrates 6 included in the master  
circuit substrate 6A. Preferably, the wire bonding  
process of FIG.5C is conducted first by bonding an end  
35 of the bonding wire 4 to an electrode pad on the wafer  
10, followed by bonding an opposite end of the bonding  
wire 4 to an electrode pad on the master circuit

1 substrate 6A. By doing so, it becomes possible to  
reduce the loop height of the bonding wire 4.

Next, in the step of FIG.5D, the bonding  
wire 4 is embedded into the resin potting 1, which is  
5 provided along the scribe line 51 as indicated in  
FIG.5D, and the solder bumps 7 are formed on the top  
surface of the master circuit substrate 6A as  
indicated in FIG.5E. The solder bump 7 is formed  
easily by causing a reflowing of a solder ball which  
10 is placed on the electrode pad 8c shown in the oblique  
view of FIG.4. By covering the solder ball by a flux  
layer and transferring the flux layer to the electrode  
pad 8c, the formation of the semi-spherical solder  
bump 7 is achieved successfully upon reflowing of the  
15 solder ball.

The structure thus obtained is then diced in  
the step of FIG.5F by applying a dicing saw 50 along  
the dicing line 51, and the semiconductor device 5 of  
FIG.3 is obtained. As a result of the foregoing  
20 dicing process, the semiconductor wafer 10 is divided  
into individual semiconductor chips 2. Similarly, the  
master circuit substrate 6A is divided into individual  
circuit substrates 6.

The semiconductor device 5 thus formed has a  
25 characteristic feature that the side wall of the  
semiconductor chip 2 forms a flush surface with a side  
wall of the resin potting 1 and that the side wall of  
the semiconductor chip 2 is substantially  
perpendicular to the principal surface of the  
30 semiconductor chip 2. Further, the foregoing  
fabrication process, particularly the dicing process  
of FIG.5F is advantageous for avoiding the problem of  
chipping of the semiconductor chip, by protecting the  
semiconductor wafer by the resin potting 1 along the  
35 scribe line 51.

FIG.6A shows a preferable modification of  
the wire bonding process of FIG.5C conducted by a

1 bonding tool 52, in which the master circuit substrate  
6A includes a depressed region adjacent to the scribe  
line 51, and it can be seen that an electrode pad 8b  
is formed on such a depressed region. As indicated in  
5 FIG.6A, the electrode pad 8b is connected to a  
corresponding electrode 8a on the wafer 10 by the  
bonding wire 4. The construction of FIG.6A is  
advantageous for reducing the loop height of the  
bonding wire 4.

10 FIG.6B shows a part of the semiconductor  
device that is formed from the half-product of FIG.6A.

Referring to FIG.6B, it can be seen that the  
semiconductor device has an advantageous feature in  
that the bonding wire 4, and hence the resin potting 1  
15 holding the bonding wire 4 therein, is substantially  
accommodated in the depression formed at the edge of  
the circuit substrate 6A facing the scribe line 51.  
Thus, the risk that the solder bumps 7 on the top  
surface of the circuit substrate 6A failing to make a  
20 contact with an external electronic device due to the  
projection of the resin potting 1 is positively  
eliminated. Associated therewith, it should be noted  
that the size or diameter of the solder bumps 7 can be  
reduced without causing a problem of failure of  
25 contact with the external electronic device.

As already noted, the present invention as  
set forth above with reference to the first embodiment  
successfully eliminates the complex and time-consuming  
alignment process for achieving a proper alignment  
30 between a semiconductor chip and a corresponding  
minute circuit substrate, and the efficiency of  
production of the BGA semiconductor device is improved  
substantially.

35 [SECOND EMBODIMENT]

FIG.7 shows a fabrication process of a BGA  
semiconductor device 15 according to a second

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1 embodiment of the present invention.

Referring to FIG.7, the semiconductor wafer  
10 carries an adhesive layer 13a corresponding to the  
adhesive layer 3a, and a master circuit substrate 16A  
5 is provided on the adhesive layer 13a in  
correspondence to the master circuit substrate 6A of  
FIG.5F. Further, spherical or semi-spherical solder  
bumps 17 are provided on the top surface of the master  
circuit substrate 16A in correspondence to the solder  
10 bumps 17.

In the present embodiment, the groove 51  
formed in the master circuit substrate 16A and  
exposing the top surface of the wafer 10 is not used  
for the scribe line, and the electrode pads on the  
15 exposed top surface of the wafer 10 along the groove  
51 are connected electrically to corresponding  
electrode pads on the master circuit substrate 16A by  
way of respective bonding wires 14. The bonding wires  
14 are further embedded into a resin potting 11.

20 In the present embodiment, a groove 61 is  
formed at a location bisecting the region of the  
master circuit substrate 16A located between a first  
groove 51 and an adjacent groove 51, and the dicing is  
conducted along the groove 61 by applying a dicing saw  
25 to the groove 61 in a state that the groove 61 is  
filled by a resin potting similar to the resin potting  
1.

FIG.8 and 9 show the BGA semiconductor  
device 15 of the present embodiment in detail  
30 respectively in a cross sectional view and in an  
oblique view for a state after the dicing process is  
conducted.

Referring to FIGS.8 and 9, it should be  
noted that electrode pads 18a corresponding to the  
35 electrode pads 8a are provided on the exposed top  
surface of the chip 12, wherein the chip 12 is formed  
as a result of dicing of the wafer 10 along the scribe

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1 lines 61 of FIG.7.

2 The electrode pads 18a are formed in the  
3 groove in a criss-cross pattern, and each electrode  
4 pad 18a is connected to a corresponding electrode pad  
5 18b provided on the top surface of the circuit  
6 substrate 16, which is obtained as a result of the  
7 dicing of the master circuit substrate 16A, by a  
8 bonding wire 14. The circuit substrate 16 further  
9 carries a number of conductor patterns 19 each  
10 extending between an electrode pad 18a and an  
11 electrode pad 18c, wherein the electrode pad 18c is  
12 provided on the top surface of the master circuit  
13 substrate 16A and hence on the top surface of the  
14 circuit substrate 16 in correspondence to the  
15 electrode pad 8c of FIG.4. Further, the top surface  
16 of the circuit substrate 16 is protected by a solder  
17 resist 13b except for the part where the solder bumps  
18 17 are formed.

19 In the BGA device of the present embodiment,  
20 the bonding wires 14 are used to connect the  
21 corresponding electrode pads 18a and the electrode  
22 pads 18b at a central part of the chip 12, as  
23 indicated in FIG.8. Further, the BGA semiconductor  
24 device of the present invention is laterally  
25 surrounded by the resin potting 1.

26 The fabrication process of the BGA device of  
27 the present invention is substantially identical with  
28 that of the BGA device of the first embodiment, except  
29 that there is a difference in the shape of the circuit  
30 substrate 16 or in the location of the groove in which  
31 the wire bonding is made.

32 The present embodiment is advantageous in  
33 the point that it enables a saving of the area that is  
34 used for achieving the wire bonding process.

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#### [THIRD EMBODIMENT]

FIG.10 shows the construction of a BGA

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1 semiconductor device 25 fabricated according to a  
third embodiment of the present invention.

Referring to FIG.10, the semiconductor  
device 25 includes a circuit substrate 26  
5 corresponding to the circuit substrate 6, wherein the  
circuit substrate 26 is formed of a polyimide film  
carrying thereon a conductor pattern and is mounted on  
a semiconductor chip 22 corresponding to the  
semiconductor chip 2 without an intervening adhesive  
10 layer. The conductor pattern on the polyimide film 26  
may be formed by an etching process. On the polyimide  
film 26, there are provided a plurality of semi-  
spherical solder bumps 27 in correspondence to the  
solder bumps 7 on the circuit substrate 6. The  
15 foregoing conductor pattern on the polyimide film 26  
is connected to the electrode pads on the  
semiconductor chip 22 by way of bonding wires 24.  
Further, the bonding wires 24 are embedded in a resin  
potting 21, wherein it should be noted that the resin  
20 potting 21 further supports the polyimide film 26 on  
the top surface of the semiconductor chip 22.

Hereinafter, the fabrication process of the  
BGA device 25 of the present invention will be  
described with reference to FIGS.11A - 11F.

25 Referring to FIG.11A, the polyimide film 26,  
which carries thereon the conductor pattern, is  
aligned with respect to the Si wafer 10. In FIG.11A,  
it should be noted that the polyimide film 26 forms a  
continuous film as indicated by a broken line. On the  
30 other hand, the polyimide film 26 includes a cutout in  
correspondence to the broken line, and the top surface  
of the Si wafer 10 is exposed at the foregoing cutout.  
It should be noted that the polyimide film 26 is  
disposed on the wafer 10 such that the cutout is  
35 aligned with the scribe line 51 defined in the wafer  
10.

The polyimide film 26 thus aligned is then

1 fixed temporarily on the wafer 10 by a jig such as a  
clip as indicated in FIG.11B, and a wire bonding  
process is conducted in the step of FIG.11C by using  
the bonding wire 24. Thereby, the length of the  
5 bonding wire 24 is set to be slightly larger than the  
length needed in the wire bonding process conducted in  
the state of FIG.11C.

Next, an injection of the resin 21 is  
conducted in the step of FIG.11D along a periphery of  
10 the wafer 10, and the polyimide film 26 is lifted in  
the upward direction from the wafer 10 as indicated in  
FIG.11D as a result of such an injection of the resin  
21. Thereby, the length of the bonding wire 24 is  
chosen such that the polyimide film 26 can be lifted  
15 freely in the upward direction with a predetermined  
distance. Such an injection of the resin 21 is easily  
implemented by using an apparatus that is used  
conventionally in the mounting process of a flip-chip  
package device or a BGA package device for introducing  
20 an under-fill resin between the mounting substrate and  
the chip or a BGA package.

After the step of FIG.11D, the solder bumps  
27 are formed on the corresponding electrode pads of  
provided on the polyimide film 26 as indicated in  
25 FIG.11E, and the structure of FIG.11E is diced in the  
step of FIG.11F along the scribe lines by applying a  
dicing saw 50. As a result of the dicing step of  
FIG.11F, the BGA device 25 of FIG.10 is obtained in  
which it should be noted that the chip 22 and the  
30 resin body 21 have a common, flush side wall  
perpendicular to the principal surface of the chip 22.

In the dicing step of FIG.11F, it should be  
noted that the dicing of the semiconductor wafer 10 is  
conducted in the state that the wafer 10 is protected  
35 by the resin 21. Thus, the problem of chipping of the  
diced semiconductor chip 22 is effectively avoided.

In the present embodiment, too, it should be



1     noted that the proper alignment between the individual  
chip 22 and the polyimide circuit substrate 26 is  
achieved easily, by conducting such an alignment  
process before the semiconductor wafer 10 is divided  
5     into individual semiconductor chips 22. Further, the  
present embodiment can eliminate the process of  
applying an adhesive film on the wafer 10.

Further, the present invention is by no  
means limited to the embodiments described heretofore,  
10    but various variations and modifications may be made  
without departing from the scope of the invention as  
set forth in claims.

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